Preparation of Hazard, Vulnerability & Risk Analysis Atlas and Report for the State of Himachal Pradesh

Forest Fire Hazard Risk Assessment

Composite Final Draft Report

(T6)

Prepared for

Disaster Management Cell, Department of Revenue

Government of Himachal Pradesh, Shimla

Prepared by

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New Delhi and Ahmedabad, India

March 2015

VOLUME GUIDE

This series of reports present detailed technical and methodological documentation of the study entitled "Preparation of Hazard, Vulnerability & Risk Analysis Atlas and Report for the State of Himachal Pradesh" for DM Cell, Revenue Department, Himachal Pradesh.

Volume **1**

Hazard Risk

This volume contains Technical papers on hazard risk assessment due to natural and man-made hazards within Himachal Pradesh as presented below.

1. Avalanche Hazard Risk
2. Climate Change & Flood Hazard Risk
3. Drought Hazard Risk
4. Earthquake Hazard Risk
5. Environmental & Industrial Hazard Risk
6. **Forest Fire Hazard Risk**
7. GLOF Hazard Risk
8. Landslide Hazard Risk

Volume **2**

Vulnerability and Risk

This volume contains Technical papers on the Vulnerability and Risks to key elements at risk within Himachal Pradesh as presented below.

1. Socio-Economic Vulnerability and Risk
2. Building Vulnerability and Risk

Volume

1

Hazard Risk

Forest Fire Hazard Risk Assessment

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Abbreviations

AHP	Analytical Hierarchy Process
ASTER	Advanced Space-borne Thermal Emission and Reflection Radiometer
DM	Disaster Management
GDEM	Global Digital Elevation Model
GIS	Geographic Information System
GLCF	Global Land Cover Facility
MCDM	Multi-Criteria Decision Making
MODIS	Moderate-resolution Imaging Spectro-radiometer
LULC	Land use Land cover
SAARC	South Asian Association for Regional Cooperation

Executive Summary

In Himachal, forest fires are an annual and widespread phenomenon. Most fires are witnessed during summers, when the forests become littered with dry senescent leaves and twinges thereby increasing the probability of starting and spreading of fire.

The fire season in HP starts from the month of April (SAARC-SDMC, 2007) and extend till monsoons. In June 2007, forest fire destroyed around two hundred hectares of forest in Himachal Pradesh (HP). In an another event of June 2012, forest fires destroyed more than 20,000 acres of forest land and caused a loss greater than Rs. 2 million of green property. This event, started in the Hamirpur circle but extended to neighboring districts including Shimla, Nahan and Mandi (Indian Express, 2012).

Analyzing the spatial extent and distribution of forest fires is essential for sustainable forest management. Knowledge of cause, extent and impact of forest fires on ecosystems, and their link to the goods and services that people derive from forests is limited. Without a proper understanding of the causes and effects of fire such as ecological or socioeconomic, or cultural, it is not possible to strive for fire management that meets the livelihoods needs of forest-dependent communities while also conserving forests and biodiversity. Such understanding is essential to arrive at negotiated tradeoffs in integrating actual fire management practices into existing forest management.

In this study an attempt was made to model the forest fire risk zones based on historical data collected from national and international organizations. Medium to high resolution satellite imageries were used to validate the presence of scar or fire damage. The results of the analysis indicate that majority of districts in HP are under high to very high fire risk zones. Within each of these high risk districts, more than 56% of area are prone to or have the possibility of being affected by fires. For example, Sirmaur has around 86% of its area under high to very high risk zone followed by Hamirpur (78%), Shimla (74%) and Mandi (73%). The district of Solan has experienced maximum number of forest files over the last 8 years (since 2005) followed by Una and Mandi. But the extent of fire damage has been found to be more in the district of Shimla followed by Kangra and Chamba.

Chapter 1: Introduction

1.1 Background: Forest Cover in Himachal Pradesh

The forests of the Himachal Pradesh can be classified into two major categories including Coniferous Forests and Broad-leaved Forests. Distribution of various species follows fairly regular altitudinal stratification. The vegetation varies from Dry Scrub Forests at lower altitudes to Alpine Pastures at higher altitudes. In between these two extremes, distinct vegetational zones of Mixed Deciduous Forests, Bamboo, Chil, Oaks, Deodar, Kail, Fir and Spruce, are found.

The richness and diversity of the flora can be gauged from the fact that, out of total 45,000 species found in the country as many as 3,295 species (7.32%) are reported in the State. More than 95% of the species are endemic to Himachal Pradesh and characteristic of Western Himalayan flora, while about 5% (150 species) are exotic, introduced over the last 150 years (HP Forest Dept., 2013).

Existing scenario of land utilization in Himachal Pradesh is described in the Table 1.

Table 1: Land Utilization of Himachal Pradesh

Land Type	Area (in Sq. Km)	% of Total Area
Forest Area (Forest Record)	37,033	67%
Land put to Non-agricultural uses	4,716	8%
Net area sown	5,414	10%
Fallow Lands (Current & other Fallows)	752	1%
Culturable Wastes	1,280	2%
Land under misc. tree crops not included in cultivation	611	1%
Permanent pastures and other grazing lands including alpine pasture, barren & un-culturable lands including alpine pastures, barren & un-culturable waste etc.	5,867	11
Total Geographical Area	55,673	100

Source: Himachal Pradesh Forest Department, Govt. of HP

Legal classification of forest in Himachal Pradesh is presented in Table 2.

Table 2: Legal Classification of Forest

Forest Type	Area (in Km^2)	Area (%)
Reserved Forests	1,896	5.12
Demarcated protected Forests	11,387	30.75
Un-demarcated Protected Forests	21,656	58.48
Unclassified Forests	976	2.63
Others(managed by Forest Department)	370	1.00
Not managed by Forest Department	748	2.02
Total	37,033	100.0

Source: Himachal Pradesh Forest Department, Govt. of HP

According to national Forest Policy, 1988, at-least two third (i.e. 66%) of the geographical area should be under forest in the hilly states like Himachal Pradesh.

1.2 Forest Fire in Himachal Pradesh

The forests of Western Himalayas are more frequent vulnerable to forest fires as compared to those in Eastern Himalayas. Frequency and intensity of forest fires has been increased since 1990 in Himalayan region. Forest fires are an annual phenomenon in state of Himachal Pradesh. This is a most frequent hazards.

Fire season starts from mid-April, when there is no rain for months, forests become littered with dry senescent leaves and twinges, which could burst into flames or ignited by the slightest spark. In June 2007, forest fire destroyed 2,000 hectares of forest in Himachal Pradesh (SAARC-DM Center, 2007).

Forest fires are mostly anthropogenic in nature in Himachal Pradesh and may occur due to the following reasons:

- Forest floor are often burnt by villagers to get a good growth of grass in the following season or for a good growth of mushrooms,
- Wild grass or undergrowth is burnt to search for animals,
- Firing by miscreants,
- Attempt to destroy stumps of illicit fallings.

District wise forest statistics presented in following Table 3.

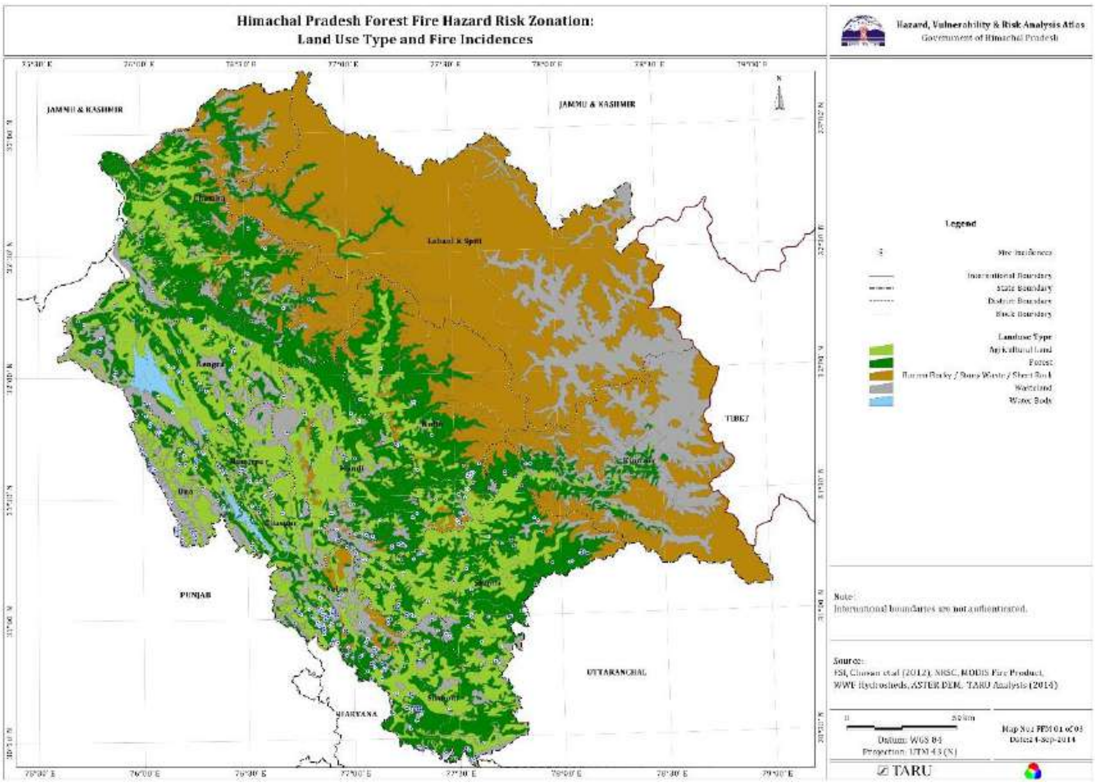
Table 3: District Wise Forest in Himachal Pradesh

District	Geo. Area (Sq. Kms.)	Forest Area (Sq. Kms.)	Tree covered area (Sq. Km.)				% of Geo. Area	Forest Fire incidents during 2005-12
			Very Dense Forest	Moderate Dense Forest	Open Forest	Total Forest Cover		
Bilaspur	1,167	428	24	171	167	362	31.02	10
Chamba	6,522	5,030	853	773	810	2,436	37.35	15
Hamirpur	1,118	219	39	92	114	245	21.91	15
Kangra	5,739	2,842	310	1,221	531	2,062	35.93	46
Kinnaur	6,401	5,093	82	263	257	602	9.40	2
Kullu	5,503	4,952	586	789	583	1,958	35.58	31
Lahaul & Spiti	13,841	10,133	15	32	146	193	1.39	37
Mandi	3,950	1,860	373	735	565	1,673	42.35	69
Shimla	5,131	3,418	739	1,037	608	2,384	46.46	29
Sirmaur	2,825	1,843	130	568	685	1,383	48.96	39
Solan	1,936	728	55	404	390	849	43.85	104
Una	1,540	487	18	298	205	521	33.83	85
Total	55,673	37,033	3,224	6,383	5,061	14,668	26.35	482

Source: Forest Department, Govt. of HP, Forest Survey of India, Dehradun

Figure 1 shows land-use type and fire incidences in the state of Himachal Pradesh.

Figure 1: Himachal Pradesh: Land Use Type and Fire Incidences



Source: Global Land Cover 2000, Forest Department, Govt. of HP, Forest Survey of India, Dehradun.

Chapter 2: Objective

The main objective of this study was to “assess and develop forest fire risk zone map using multi-parameter analysis which includes like fuel type, forest density, distance to roads, distance to villages, distance to rivers or any other surface water, topographic (slope, aspect and elevation) at block level across the Himachal Pradesh state based on historical events’.

Chapter 3: Literature Review

Forests are a major natural resource, which play crucial role in maintaining environmental balance. The health of forest in any given area is a true indicator of the ecological condition prevailing in that area. Frequent occurrence of forest fires may lead to depletion or extinction of some of the valuable plant and animal species. Even human beings are adversely affected either directly or indirectly. Thus forest fires can be considered to be a potential hazard with physical, biological, ecological & environmental consequences which results in partial or complete degradation of vegetation cover thus modifying the radiation balance by increasing the surface albedo, water runoff and raising the soil erosion (Darmawan and Mulyanto, 2001). Fuel is any material capable of burning. In forests, fuels are vegetation, branches, needles, standing dead trees, leaves, and man-made flammable structures (Anon, 1999). Technically, fire is defined as the rapid combustion of fuel, heat and oxygen. All these three elements are in some proportion to start and spread fire. It is a chemical reaction of any substance that will ignite and burn to release a lot of energy in the form of heat and light (Rawat, 2003). To start a fire an external source of heat is required along with oxygen. Heat is measured in terms of temperature.

3.1 Categories of Forest Fires

The fire can be defined as an uncontained and freely spreading combustion which consumes the natural fuels of a forest i.e. duff, litter, grass, dead branch, wood, snags, logs, stumps, weeds, brush, foliage and to some extent green trees (Brown and Davis, 1959). Basically forest fires have been categorized in to three categories.

- **Ground Fires:** Ground fires are not easily predictable as it spreads within the canopies rather than top of organic matter. It consumes organic matter like duff, musk or peat present beneath the surface litter of the forest floor. It has unique characteristic of having a smouldering edge with no flame and little smoke. Ground fires are most hard to handle and there should be proper policy and practices for control agencies.
- **Surface Fire:** Surface fire is characterized by a fast moving fire, which consumes small vegetation and surface litter along with loose debris.
- **Crown Fire:** Crown fires advances from top to top of trees or shrubs without any close link with surface fire. It is fastest to spread and most destructive for trees and wildlife.

3.2 Causes of Forest Fires

Basically causes of forest fire have been classified into three main categories

Natural: These are the fires which cannot be averted as these occurs naturally due to lightening, rolling of stones & rubbing of dry bamboos due to strong wind.

Intentional/Deliberate: Mainly intentional fires are created for the better growth of fodder grass. These fires are also been set by villagers to drive away the herbivores animals which destroy their crops. Sometimes villages get annoyed with forest Department and deliberately set fire without knowing its consequences. Villagers also set fire for collecting forest products like honey, gum, Mahua flowers etc. Railway transport also causes forest fires occasionally. Forest has less control over fires which are caused deliberately by local dwellers.

Un-intentional/Accidental: Unintentional/ Accidental fires are result of carelessness of human beings such as throwing of burning match stick or cigarette. Other fires which occur accidentally are the spread of fire from labour camps, from picnic sites and other recreational areas due to human activities.

These types of fires are controlled by certain parameters like its proximity to settlements and distances from roads. Although it is not easy to account natural or deliberate fires but the areas prone to fires can be detected and mapped.

3.3 Parameters responsible for Forests Fire

The factors required for any fire to take place are availability of air, fuel and heat. Forest fire behavior is dependent on its intensity, spread and integrated factors. These factors are.

Vegetation Type / Density: Dense and dry vegetation are more susceptible to fire in comparison to moist and sparse one. Moisture content of vegetation delays ignition.

Climatic Factors: Climate plays the dominant role in ascertaining the fire prone areas as they are the main determining factor of vegetation of a given region. Thus drier the climate the more prone is the site for fire.

Physiographic Factors: Physiographic factors include altitude, aspect and topography of a region. These are the factors, which are mainly responsible for variation in climatic conditions. Thus they indirectly affect the vegetation. Aspect plays one of the major roles in the spread of fire like southern slops which are more or less directly exposed to sun rays are more vulnerable to fire.

Topography: Topography influence the wind of a particular region like fire travels more rapidly in up slopes.

Edaphic factors: Soil plays a vital role in the growth, development & anchoring of the vegetation. And vegetation after decay adds to the fertility of the soil.

Distance to Roads: Any physical activity by man, animal or vehicle on the road can cause an unwanted fire. Thus proximity to the road plays vital role in chance of fire.

Vicinity to Settlements: In settlement lots of human activities can cause fire in the vicinity of settlement, which can spread a forest fire & cause a lot of havoc.

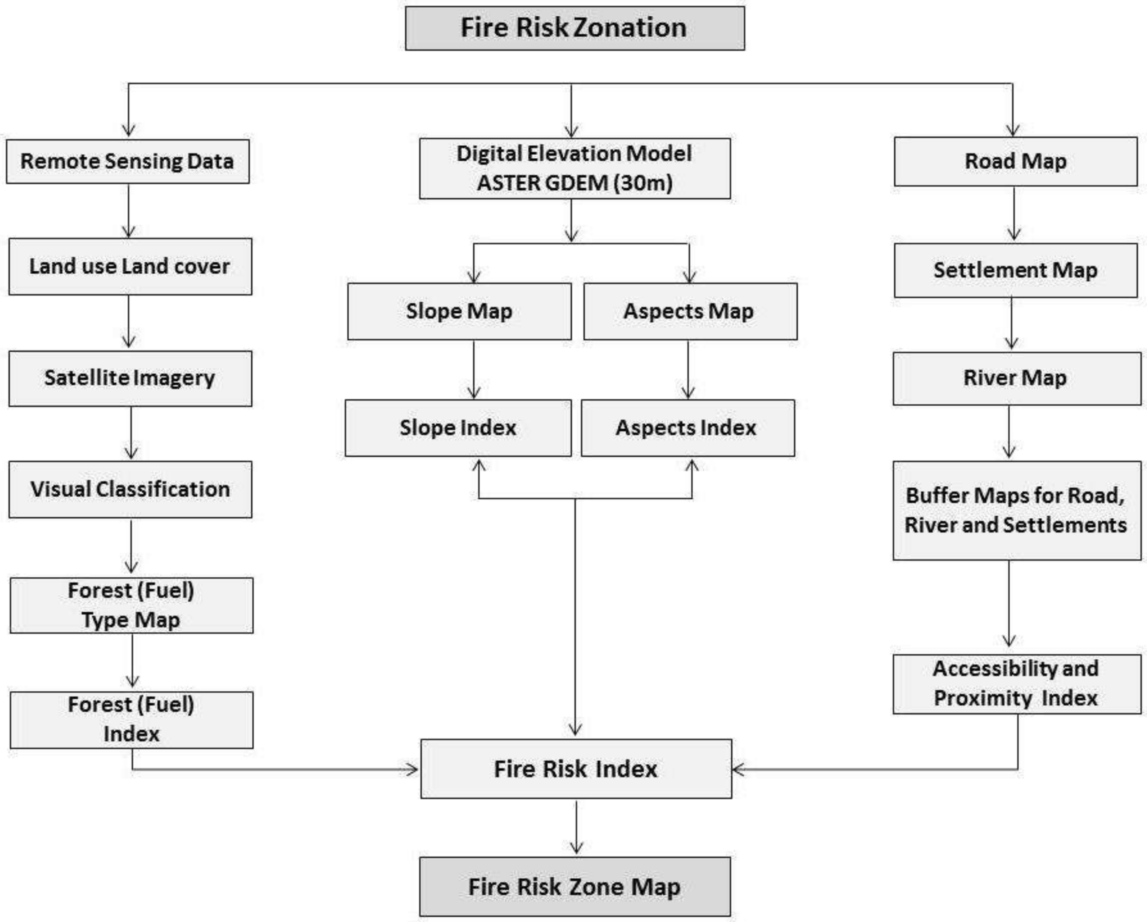
Some of the main causes of forest fire in Himachal Pradesh are as folliws:

- Illegal activities including logging.
- Controlled fire to clear residual material along inspection corridors within forest.
- Set fire in order to collect non-wood forest products from interior of the forest.
- To grow fresh grass for the next season.
- Lighting oil lit lamps in places of worship which are situated within forests or in its periphery.

Chapter 4: Methodology

The scope of this assessment was limited to assessing forest fire risk and in its zonation. Detailed methodology flow chart has been given in Figure 2.

Figure 2: Methodology



Source: Chavan et al., 2012, Sharma et al., 2009

4.1 Data Used

Following spatial data has been acquired from various sources for forest fire hazard risk assessment.

- State, district & block/taluka boundaries (Survey of India)
- Settlements locations (Survey of India)
- Road network (Open access database)
- Elevation data (ASTER GDEM 30 m)

- Land use and land cover (GLCF)
- River network and water bodies (Hydrosheds & Google Earth Pro)
- Historical fire events (MODIS Burned Area, Forest Survey of India)

4.2 Process and Methods

In this study, Saaty's (2000) Analytical Hierarchy Process (AHP) method was used for risk mapping and zonation. AHP is a multi-criteria decision making (MCDM) method in conjunction to rank and prioritize the causative factors of fire risk in the study area.

4.2.1 Analytical Hierarchical Process (AHP)

Spatial multi-criteria decision analysis is a process that combines and transforms geographical data (input) into a resultant (output). The multi-criteria decision making procedures define a relationship between the input map and the output map. This procedure utilizes the geographical data, the decision maker's preferences, and the manipulation of the data and preference according to the specified decision rules. Multi-criteria analysis has been used for the evaluation of geographical events (Malczewski 1999).

Analytical hierarchical process is a decision-aided method developed by Saaty. It aims at quantifying relative priorities for a given set of alternatives in a ratio scale, based on the judgments of a decision maker as well as the consistency of the comparison of alternatives in the decision making process. This method has been forced to an effective and practical approach that can consider complex and structured decision. The AHP is proposed in this research in order to assess weightages for various parameters influencing the forest fire. T weights have been decided following the analytical approach suggested by Saaty (1990). A spatial process model has been developed for the decision making.

In this study, AHP was used to organize decision making criteria. Pairwise comparison matrixes were made between criteria at each level of the hierarchy and possible alternative causes of decision.

These comparison matrixes, lead to priority vector, which are the weights for respective layers. These priority vectors propagated through the hierarchy to get the final priority vector and thus the weights. The methodology consisted of four different components:

- Hierarchical structure development of fire risk criteria,
- Weights determination at different levels of hierarchy using linguistic variables and fuzzy sets,
- Assigning criteria weights in GIS, and
- Fire risk quantification using decision rule.

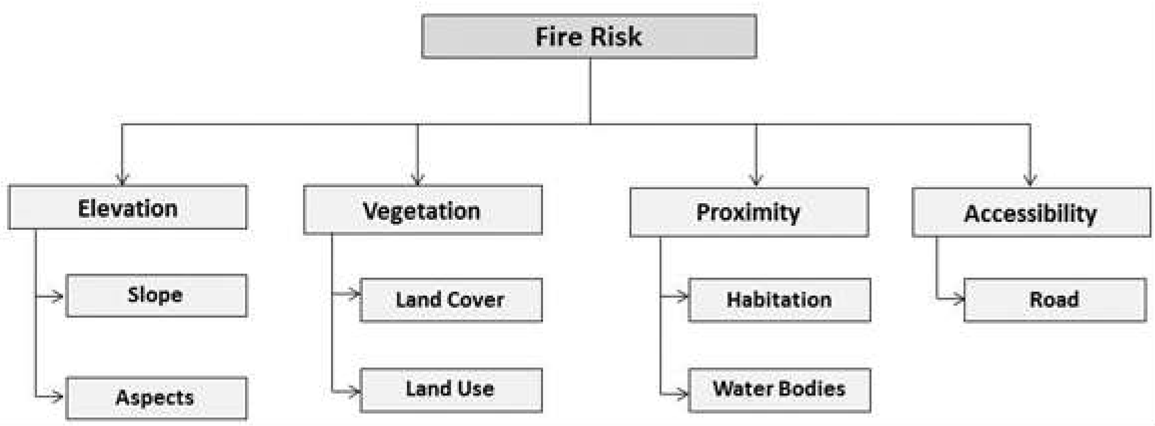
4.2.2 Development of Fire Risk Criteria: Hierarchical Structure

Forest fire depends on multiple factors with varying influence. Different physical parameters have different characteristics which contribute to either the ignition of fire or its spread. Some parameters play more significant role then others in forest fire. Therefore, in modeling these parameters are to be considered but assigned weightage according to their contribution.

In this study, physical parameters that were considered for modeling included elevation, slope & aspects, vegetation type, proximity and accessibility parameters such as access to road and water bodies. The integration of these factors was done using a hierarchical approach. Assumptions were made so that every layer has and its influence are quantified.

The hierarchical structure for quantifying fire risk was designed based on the analytical hierarchy model as indicated by Saaty (2000). Hierarchical structure of causative factors of forest fire is presented in Figure 3.

Figure 3: Fire Risk Assessment: Hierarchical Structure of Causative Factors



Source: Vadrevu et al., 2009

4.3 Vegetation Parameters

Vulnerability of the forest to fire hazard has been mapped based on vegetation type (land cover). Vegetation is also well known as fuel in forest fire risk assessment. Fuel index plays a very important role in fire risk assessment which generally derived from fuel type and fuel load (Chavan et. al. 2012).

Vegetation was considered as a key parameter for classification because some vegetation types are more flammable than others, thereby increasing the fire hazard. Fuels represent the organic matter available for fire ignition and combustion (Rothermel 1983; Albini 1976). In this study, land cover (forest type) has been used as a vegetation parameter.

In this study, vegetation type was derived from Global Land Cover (GLC, 2000) data (fuel type). For the present study fuel type was considered as main factors that affects the spread of forest fire. Fuel type accounted for the over story (canopy cover) and whereas fuel load for the understory vegetation as they represent the total fuel available for fire.

4.3.1 Topographic Parameters

For the past several years, fire behavior models have incorporated the interaction of fire spread with fuels, weather, and terrain (Albini 1976; Rothermel 1983). Some effects were accounted for fire line intensity (Rothermel 1983). Other terrain effects on fire intensity and spread were incorporated indirectly through fuel type and moisture. The effect of terrain attributes on forest survival following wildfire has been assessed by Kushla and Ripple (1997) and others. Three different topographic parameters explained below, as causative factors of fires; these included elevation, slope, and aspect. Most of these parameters were derived from ASTER GDEM (30 m).

(a) Elevation: It is an important physiographic factor that is related to wind behavior and hence affects fire proneness (Rothermel 1983). Fire travels most rapidly up-slope and least rapidly down-slope. Elevation values (in m) for fire pixels have been extracted from ASTER GDEM (30m).

(b) Slope: It is an indicator of rate of change of elevation (degrees). Slope affects both the rate and direction of the fire spread. Fires usually move faster uphill than downhill (Rothermel 1983; Kushla and Ripple 1997).

(c) Aspect: Describes the direction of the maximum rate of change in elevation between each cell and its neighbors. A slope with an east aspect will get direct sunlight earlier in the day than a slope with a west aspect. Also, a north-facing slope receives less sunlight than a south facing slope. Thus, Southern aspects receive more direct heat from the sun, drying both the soil and the vegetation.

In this study, aspect was derived from ASTER GDEM (30m) data. Aspect and exposure are very much related to the rate of fuel drying and spreading of the fire. The direction of the slope determines how much sunlight it receives. South and west slopes receive the most sunlight, and so they are much warmer and drier than North Slope, which get the least amount of sunlight. Areas exposed to direct sunlight present the higher degree of fire risk because of higher insolation and it corresponds to the main direction of the wind. The variation in sunlight means that all slopes have different micro-climates. Different species and amounts of vegetation grow in the different microclimates. Because north slopes and deep ridges receive less sun, they hold more moisture and so stay green longer and support more vegetation than south slope do.

Slope was derived from ASTER GDEM (30m) data. Slope has significant role in spread of fire. A forest fire is oftentimes associated with the slope due to more efficient convective preheating and ignition by point contact. Steep slopes greatly speed up the burning rate and the rate of spread of a small fire. When the head of a fire or a spot from it becomes established on a steep slope, a fast run to the top can be expected. The rate of spread is the relative activity of a fire in extending its horizontal dimensions. Consequently, the steeper the slope, the faster.

4.3.2 Proximity and Accessibility Parameters

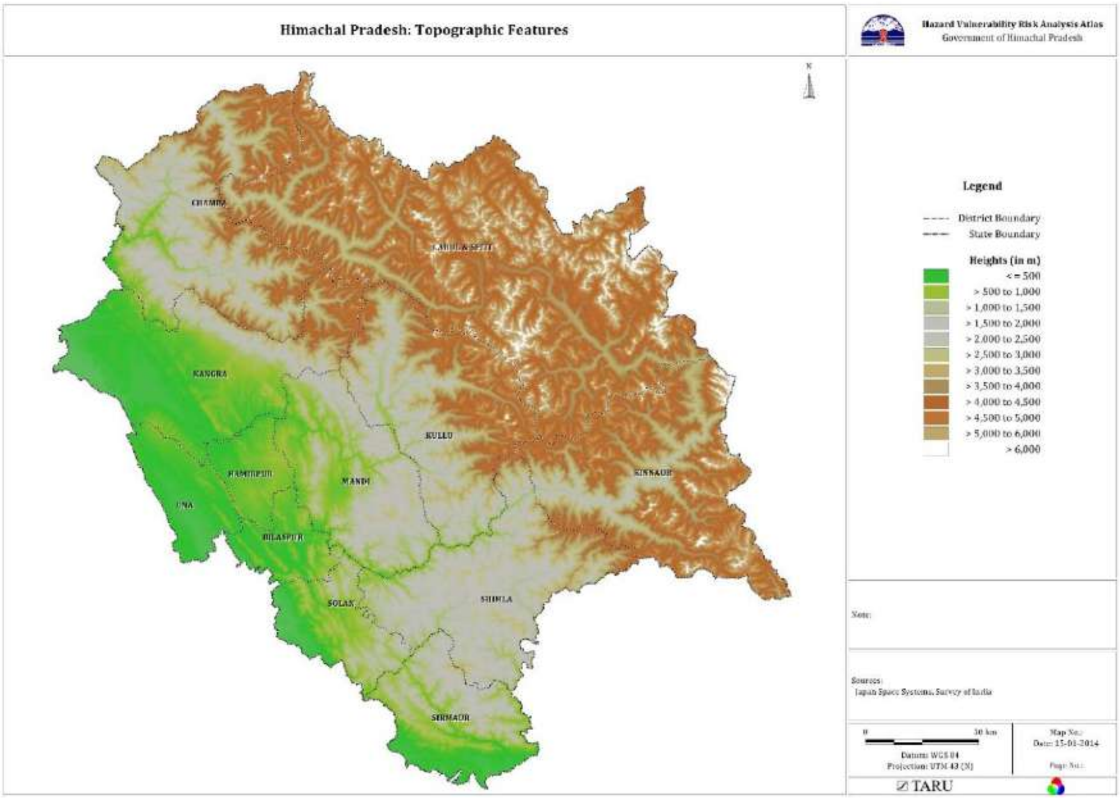
Human activities inside the forest area considered as one of the main causes of forest fires. The state of Himachal Pradesh have many small and scattered settlements within close proximity to forest which have high risk of forest fire. Fuel wood collection and grazing by local inhabitants in the close proximity to forest are common activities which lead to high risk to forest.

The presence of roads and footpaths are also important factors in fire risk mapping. There are two major effects that can be associated with them. First, they are the potential routes of hiking and used as ideal camping ground/areas. As such, they increase forest fire risk because of more intense human activity. Second, they can serve as firebreaks or pathways for suppression of the fire. In this context, they reduce the risk of fire.

Proximity to settlements, rivers and accessibility to roads are important factors that must be considered in fire risk assessment (Chavan *et al.*, 2012). These have two major effects on forest fire risk. Water bodies & rivers serve as firebreaks, thus reducing the impact of fire. Whereas, settlements, roads and trails render the forest highly vulnerable to forest fire due to more intense human activity.

Topographic features of the Himachal Pradesh are presented in Figure 4.

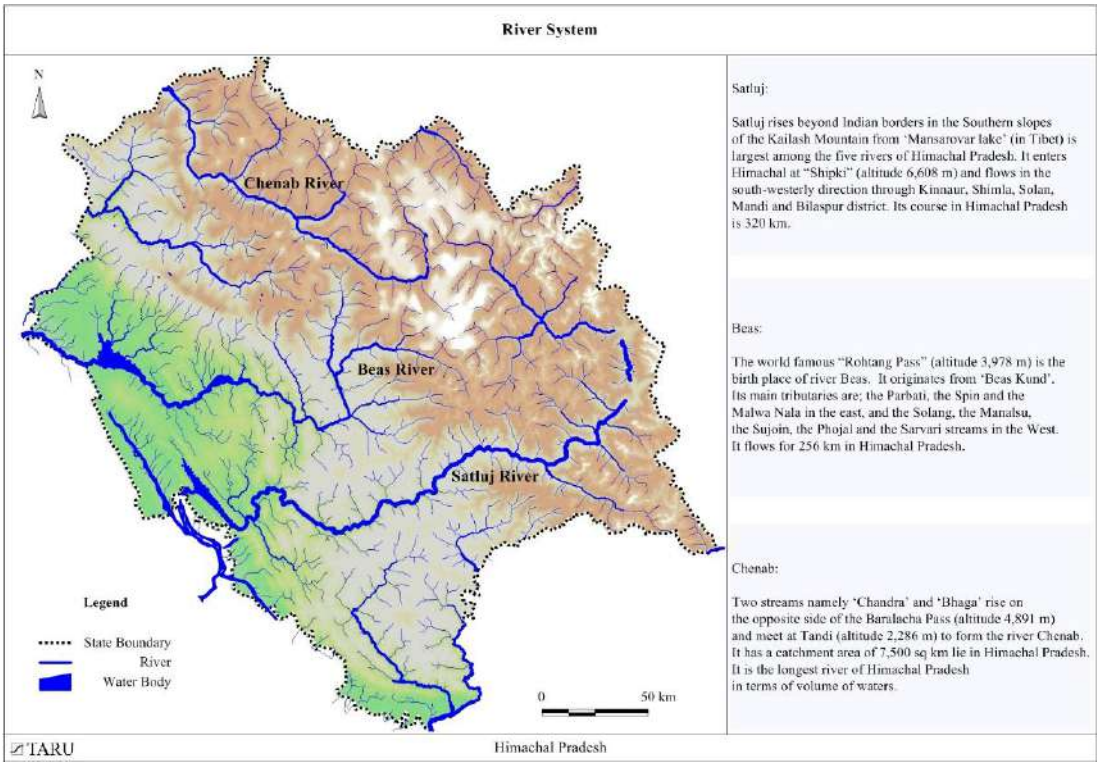
Figure 4: Himachal Pradesh: Topographical Features



Source: TARU Analysis, 2013

River system of the Himachal Pradesh is presented in Figure 5.

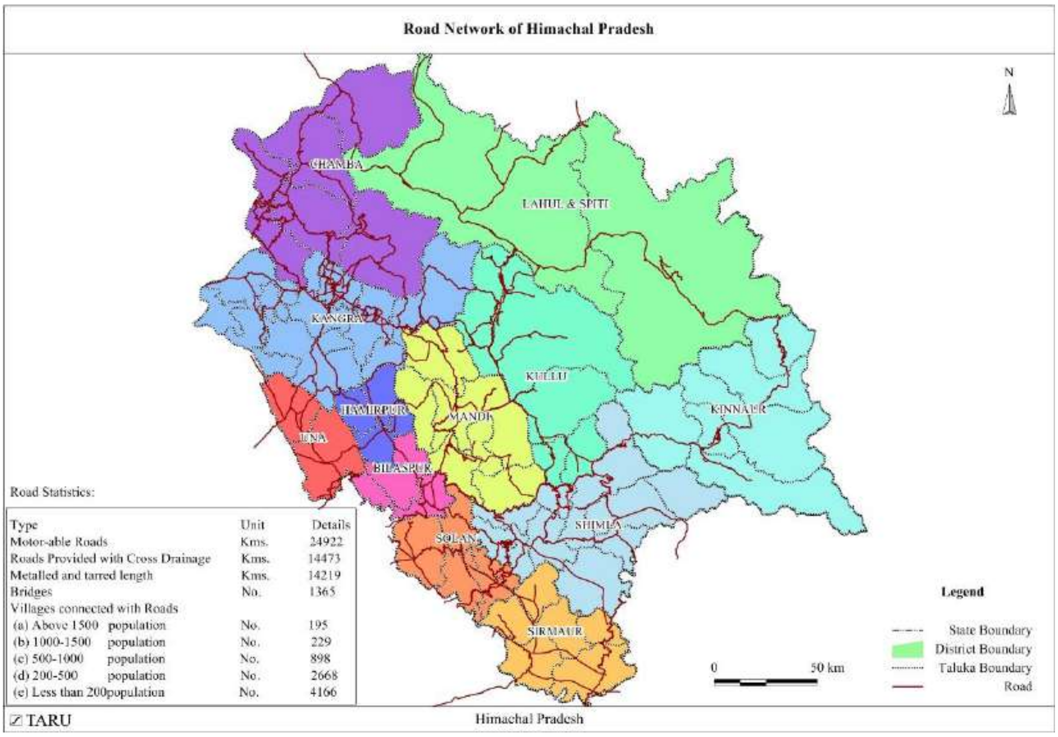
Figure 5: Himachal Pradesh: River System



Source: TARU Analysis, 2013, Hydrosheds, 2013.

Road network of the Himachal Pradesh is presented in Figure 6.

Figure 6: Himachal Pradesh: Road Network



Source: TARU Analysis, 2013, Open Source Database.

Chapter 5: Results

The fire hazard assessment followed various steps. Pairwise ranking and their respective weights which were derived using the AHP is presented in Table 4 & Table 5.

Table 4: Pairwise Ranking

Ranking	Distance from Road	Slope	Aspect	Distance from Habitation	Distance from Drainage	Land Cover
Distance from Road	1.0	0.33	0.40	0.50	0.66	0.286
Slope	6.0	1.00	1.20	1.50	2.00	0.857
Aspect	5.0	0.50	1.00	1.25	1.66	0.714
Distance from Habitation	4.0	0.33	0.80	1.00	1.33	0.571
Distance from Drainage	3.0	0.33	0.60	0.75	1.00	0.429
Land cover	7.0	0.25	1.40	1.75	2.33	1.000
Sum	26.0	2.75	5.40	6.75	9.00	3.857

Table 5: Pairwise Weights

Weight	Distance from Road	Slope	Aspect	Distance from Habitation	Distance from Drainage	Land Cover
Distance from Road	0.038	0.121	0.074	0.074	0.074	0.074
Slope	0.231	0.364	0.222	0.222	0.222	0.222
Aspect	0.192	0.182	0.185	0.185	0.185	0.185
Distance from Habitation	0.154	0.121	0.148	0.148	0.148	0.148
Distance from Drainage	0.115	0.121	0.111	0.111	0.111	0.111
Land cover	0.269	0.091	0.259	0.259	0.259	0.259
Sum	1.000	1.000	1.000	1.000	1.000	1.000

5.1 Forest Fire Hazard Assessment Equation

To assess forest fire hazard in the state of Himachal Pradesh following equation was used.

Forest Fire Hazard Risk = Slope x 0.248 + Road x 0.033 + River x 0.057 + Settlement x 0.094 + Land cover x 0.414) + Aspect x 0.153)

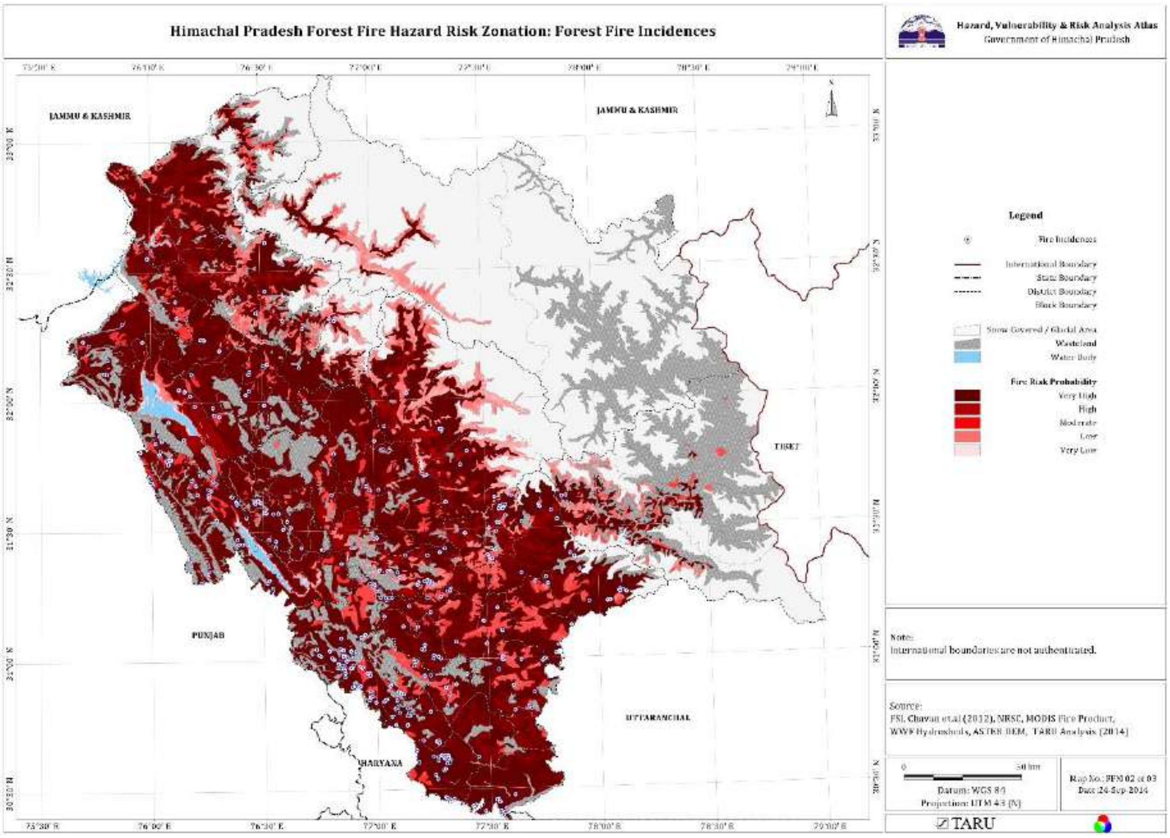
Final weights with relative importance assigned to each factor are presented in following Table 6.

Table 6: Final Weights

Fire Risk Factor	Relative Importance	Relative Importance Weight
Vegetation (Land Cover)	7	0.414
Slope	6	0.248
Aspect	5	0.153
Settlement	4	0.094
River	3	0.057
Distance from Road	1	0.033

Forest fire risk probability with fire incidences presented in following Figure 7.

Figure 7: Forest Fire Hazard Risk Zonation: Forest Fire Incidences



Source: TARU, 2013, Forest Survey of India, 2013, MODIS Fire Product, 2013, Global Land Cover 2000

5.2 Fire Risk Zonation

Fire risk zones were classified into five different categories, viz., *very high, high, moderate, low and very low risk zones*. District wise risk zone and area presented in Table 7.

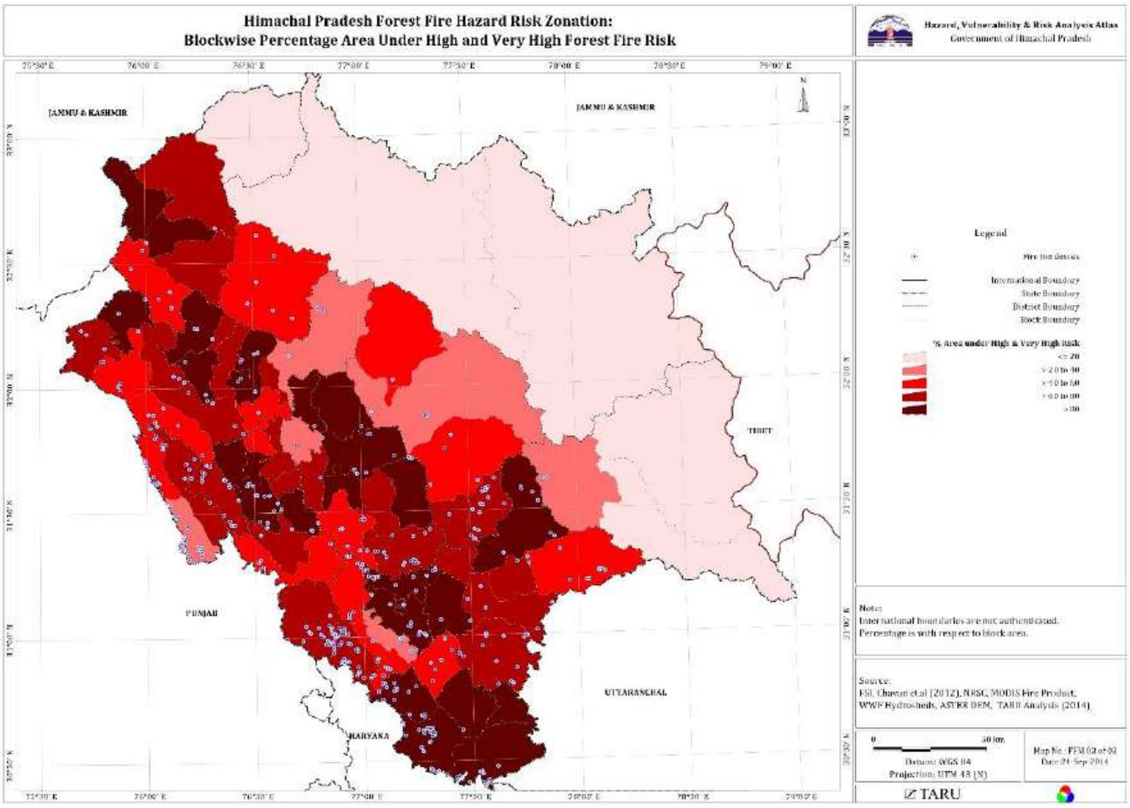
Table 7: Fire Risk Zones with District Level Statistics

District	District wise Forest Fire Risk Zones (in Sq. Km.)						
	No Risk	Very Low	Low	Medium	High	Very High	Total Area (Sq. Km)
Chamba	27	2,098	926	41	1,302	2,007	6,402
Bilaspur	87	25	214	27	561	247	1,162
Hamirpur	-	2	236	4	615	255	1,113
Kangra	208	872	959	27	2,045	1606	5,718
Kinnaur	10	4,444	1,446	9	56	502	6,468
Kullu	13	2,699	223	49	1,187	1324	5,495
Lahul & Spiti	56	12,702	823	5	72	188	13,845
Mandi	3	242	788	29	1,71	1,419	3,951
Shimla	-	469	826	13	1,658	2,147	5,113
Sirmaur	-	3	377	6	1,092	1,324	2,802
Solan	-	4	819	10	583	507	1,923
Una	44	57	505	14	720	194	1,534

Source: TARU Analysis, 2013

Figure 8 shows the different levels of risk zone and their corresponding areas in State of Himachal Pradesh.

Figure 8: Block Wise Percentage Area under High and Very High Forest Fire Risk



Source: TARU Analysis, 2013, Forest Survey of India, 2013, MODIS Fire Product, 2013

Chapter 6: Discussion and Conclusion

The results obtained through the analytical hierarchical process was quite useful in delineating potential “fire risk” zones at a block level. These maps and results can be used both as a strategic planning tool to address broad-scale fire hazard concerns and also as a tactical guide to help managers in designing effective fire control measures at local level.

The results from the analysis demonstrate the fire potential and possible spread of fire events in the state of Himachal Pradesh. To manage growing forest fires and associated fire hazards, as well as prioritize prescription efforts, it is essential to improve our understanding of the causative factors of fires. Forest fires in the mountainous regions are the result of several underlying factors. In this study, fire risk quantified in coniferous forests and broad-leaved forests in State of Himachal Pradesh, as a function of topographic, vegetation, climatic, and socio-economic attributes.

The criterion maps relating to topographic, biophysical, and socioeconomic predictors produced in this study can also be used to assess the susceptibility of any vegetation to fire and for determining future fire risks. In overall, this study demonstrates the potential of GIS technology and its viability in integrating objective as well as subjective data using fuzzy-AHP approach for assessing fire risk in the study area.

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